portion 164b of the annular resilient member 164 and the sealing lip 164c of the annular resilient member 164 to have the annular resilient member 164 reinforced with the reinforcing portion 164d. The reinforcing portion 164d of the annular resilient member 164 is made of a metal plate in the form of an annular ring shape and is of an L-shaped cross-section taken on the plane perpendicular to the center axis passing therethrough.

The annular spring member 165 of the sealing ring 163 is operative to impart a force to the sealing lip 164c of the annular resilient member 164 to ensure that the sealing lip 164c of the annular resilient member 164 is held in tight contact with the outer cylindrical surface 330b of the sleeve shaft 330. The annular spring member 165 of the sealing ring 163 is made of a metal wire in the form of a helical shape and is of a circular cross-section taken on the plane perpendicular to the center axis passing therethrough. The annular spring member 165 thus constructed is generally called "garter spring".

In the third embodiment of the shaft sealing apparatus according to the present invention, the outer cylindrical surface 330b of the sleeve shaft 330 is smaller in surface roughness Ra than 0.1 μm and larger in Vickers hardness Hv than 650.

The sealing lip 164c of the annular resilient member 164 may be held in contact with the outer cylindrical surface 330b of the sleeve shaft 330 with a vacuum grease constituted by a lubricant containing fluorine. The second sealing unit 360 may include a plurality of sealing rings 163 each having a sealing lip 164c coated with the vacuum grease. The second sealing unit 360 may also include a plurality of sealing rings 163 each having a sealing lip 164c to have the sealing lips 164c collectively form an annular groove filled with the vacuum grease. The second sealing unit 360 may also include a plurality of sealing rings 163 each having a sealing lip 164c and a subsidiary sealing lip held in contact with the outer cylindrical surface 330b of the sleeve shaft 330 to have the sealing lip 164c and the subsidiary sealing lip collectively form an annular groove filled with the vacuum grease.

The shaft sealing apparatus 300 further comprises a second bearing 369 intervening between the sleeve shaft 330 and the shaft housing 320 to have the sleeve shaft 330 movably supported by the shaft housing 320 through the second bearing 369. The second bearing 369 is located between the sealing ring 163 of the second sealing unit 360 and the second axial end of the sleeve shaft 330 in axially spaced-apart relationship with the sealing ring 163 of the second sealing unit 360.

The shaft sealing apparatus 300 further comprises second driving means constituted by an electric motor, not shown. The electric motor is operatively connected with the second axial end of the sleeve shaft 330 to rotate the sleeve shaft

330 around its own axis. While the driving means has been described in the above as being constituted by an electric motor operatively connected with the second axial end of the sleeve shaft 330, the electric motor may be replaced by a reduction gear unit and an electric motor operatively connected with the second axial end of the sleeve shaft 330 through the reduction gear unit.

The shaft sealing apparatus 300 further comprises a first labyrinth seal unit 371 intervening between the sleeve shaft 330 and the center shaft 340 to be exposed to the vacuum chamber 311 of the vacuum casing 310, and a second labyrinth seal unit 372 intervening between the shaft housing 320 and the sleeve shaft 330 to be exposed to the vacuum chamber 311 of the vacuum casing 310. The first labyrinth seal unit 371 includes an outer ring member 373 provided on the first axial end 330a of the sleeve shaft 330, and an inner ring member 374 provided on the first axial end 340a of the center shaft 340. The outer and inner ring members 373 and 374 of the first labyrinth seal unit 371 collectively form an interstice 375 therebetween to be operative to prevent dust, oil and gas from passing through the interstice 375 of the first labyrinth seal unit 371. The second labyrinth seal unit 372 includes an outer ring member 376 provided on the first axial end 320a of the shaft housing 320, and an inner ring member 377 provided on the first axial end 330a of the sleeve shaft 330. The outer and inner ring members 376 and 377 of the second labyrinth seal unit 372 collectively form an interstice 378 therebetween to be operative to prevent dust, oil and gas from passing through the interstice 378 of the second labyrinth seal unit 372.

The shaft sealing apparatus 300 further comprises a first fixed member 381 in the form of an annular ring shape and provided on the first axial end 330a of the sleeve shaft 330, a second fixed member 382 in the form of an annular ring shape and provided on the first axial end 320a of the shaft housing 320, and a base member 390 in the form of a circular shape and provided on the first axial end 340a of the center shaft 340.

The second fixed member 382 is held in axial alignment with the shaft housing 320 and fixedly connected with the first axial end 320a of the shaft housing 320 by bolts 387. The second fixed member 382 has an inner portion 388 formed with a projection, and a flange portion 389 operative to prevent the sealing rings 163 of the second sealing unit 360 from moving toward the vacuum chamber 311 of the vacuum casing 310 with respect to the sleeve shaft 330. The inner portion 388 of the second fixed member 382 constitutes the outer ring member 376 of the second labyrinth seal unit 372.

The second fixed member 382 projects from the base portion 310a of the vacuum casing 310 and extends in the vacuum chamber 311 of the vacuum casing 310.

The second fixed member 382 forms part of the shaft housing 320 extending in the vacuum chamber 311 of the vacuum casing 310. The second fixed member 382 is fixedly connected with the retaining member 361 of the second sealing unit 360 by bolts 396 to be operative to prevent the retaining member 361 of the second sealing unit 360 from rotating around its own axis with respect to the shaft housing 320.

The first fixed member 381 is held in axial alignment with the sleeve shaft 330 and fixedly connected with the first axial end 330a of the sleeve shaft 330 by bolts 383. The first fixed member 381 has an outer portion 384 formed with a pit to fit with the projection of the inner portion 388 of the second fixed member 382, an inner portion 385 formed with a projection, and a flange portion 386 operative to prevent the sealing rings 153 of the first sealing unit 350 from moving toward the vacuum chamber 311 of the vacuum casing 310 with respect to the center shaft 340. The outer portion 384 of the first fixed member 381 constitutes the inner ring member 377 of the second labyrinth seal unit 372. The inner portion 385 of the first fixed member 381 constitutes the outer ring member 373 of the first labyrinth seal unit 371.

The first fixed member 381 projects from the first axial end 320a of the shaft housing 320 and extends in the vacuum chamber 311 of the vacuum casing 310 to be operatively connected with the handling mechanism, not shown. The first fixed member 381 forms part of the sleeve shaft 330 extending in the vacuum chamber 311 of the vacuum casing 310. The first fixed member 381 is fixedly connected with the retaining member 351 of the first sealing unit 350 by bolts 395 to be operative to prevent the retaining member 351 of the first sealing unit 350 from rotating around its own axis with respect to the sleeve shaft 330.

The base member 390 is held in axial alignment with the center shaft 340 and fixedly connected with the first axial end 340a of the center shaft 340 by bolts 391. The base member 390 has an outer portion 392 formed with a pit to fit with the projection of the inner portion 385 of the first fixed member 381. The base member 390 projects from the first axial end 330a of the sleeve shaft 330 and extends in the vacuum chamber 311 of the vacuum casing 310 to be operatively connected with the handling mechanism, not shown. The base member 390 forms part of the center shaft 340 extending in the vacuum chamber 311 of the vacuum casing 310. The outer portion 392 of the base member 390 constitutes the inner ring member 374 of the first labyrinth seal unit 371.

In the third embodiment of the shaft sealing apparatus according to the present invention, the base member 390 and the first fixed member 381 collectively constitute the first labyrinth seal unit 371, and the first and second fixed members 381 and 382 collectively constitute the second labyrinth seal unit 372.